

ASAP 2001

13-14 March 2001, MIT Lincoln Laboratory, Lexington, MA, USA

Space-time adaptive FIR filtering with staggered PRI

Space-Time Adaptive FIR filtering with staggered PRI

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Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 14 MAR 2000		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Space-Time Adaptive FIR filtering with staggered PRI				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Richard Klemm				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) FGAN Wachtberg, Germany				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Defense Advanced Research Projects Agency 3701 North Fairfax Drive Arlington, VA 22203-1714				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES See ADM001263 for entire Adaptive Sensor Array Processing Workshop., The original document contains color images.					
14. ABSTRACT See report.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 14	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

ASAP 2001

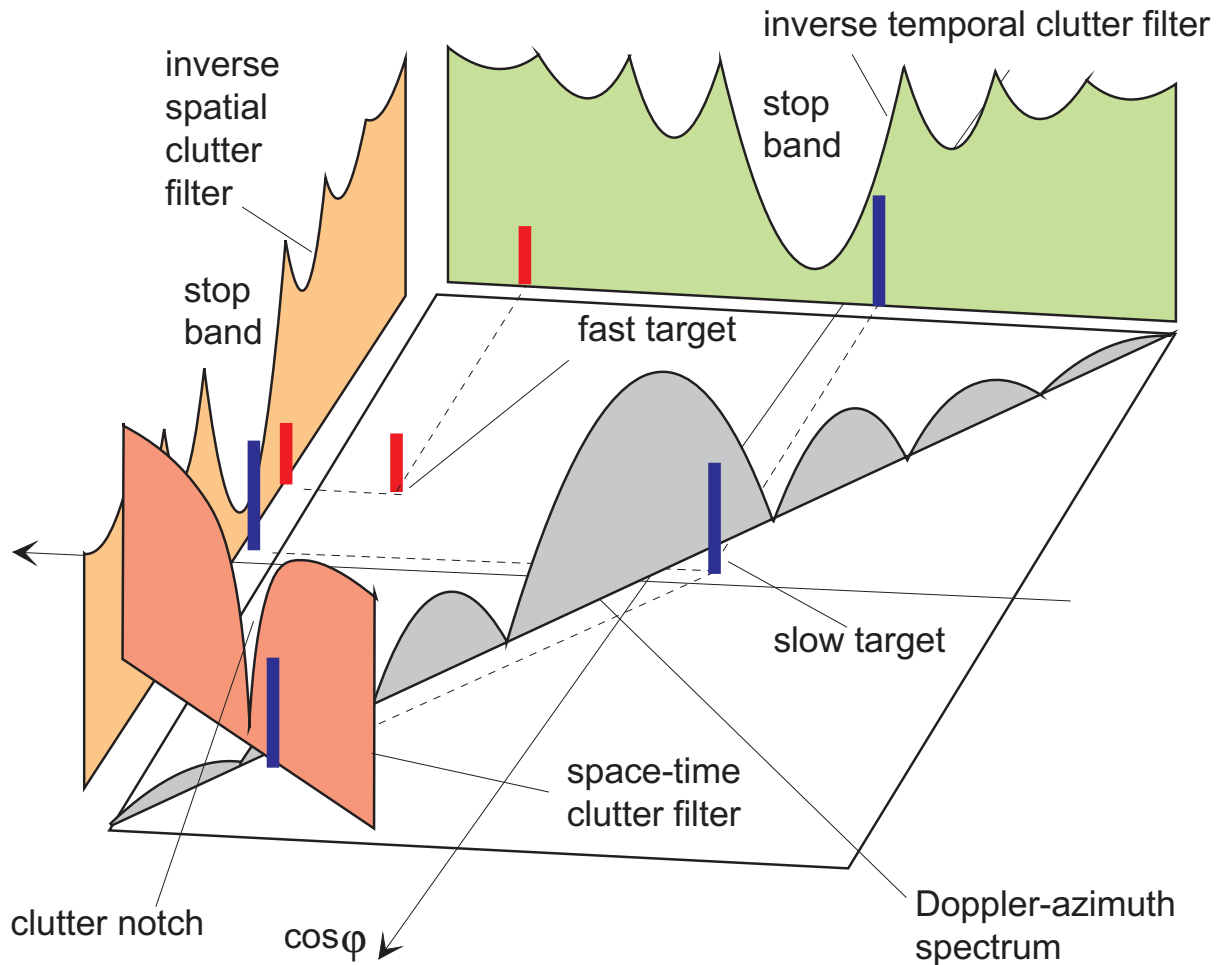
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Space-time adaptive FIR filtering with staggered PRI

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Space-time adaptive FIR filtering with staggered PRI



Principle of STAP

■ clutter spectrum ■ temporal filter ■ spatial filter ■ STAP

Principle of STAP

Space-time adaptive FIR filtering with staggered PRI

The optimum processor

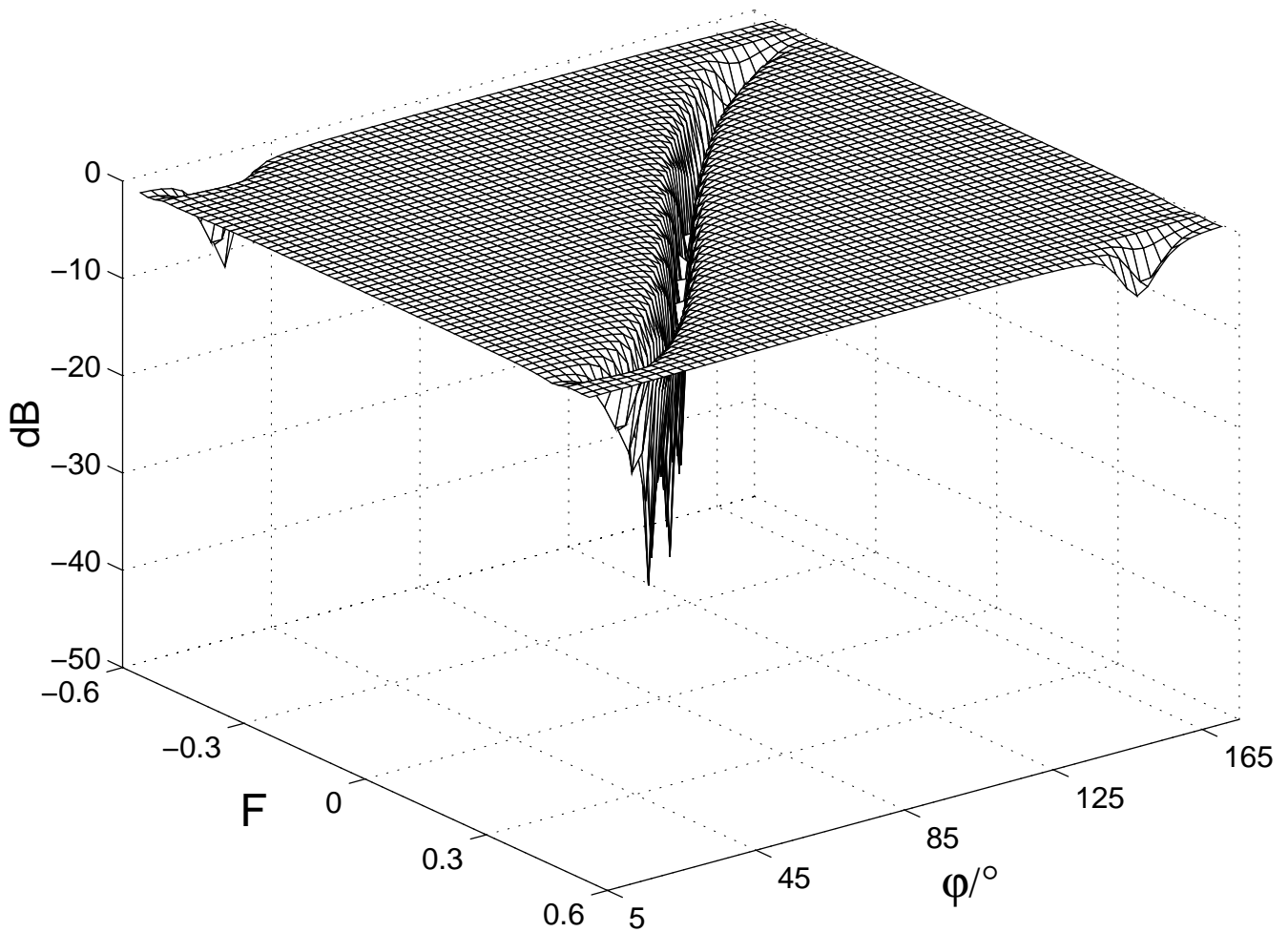
$$\mathbf{w} = \mathbf{a} \mathbf{Q}^{-1} \mathbf{s}(\mathbf{j}, v)$$

Q space-time clutter+noise covariance matrix

s space-time steering vector

For large dimensions N, M not realizable by various reasons
(amount of computations, lack of training data, accuracy)

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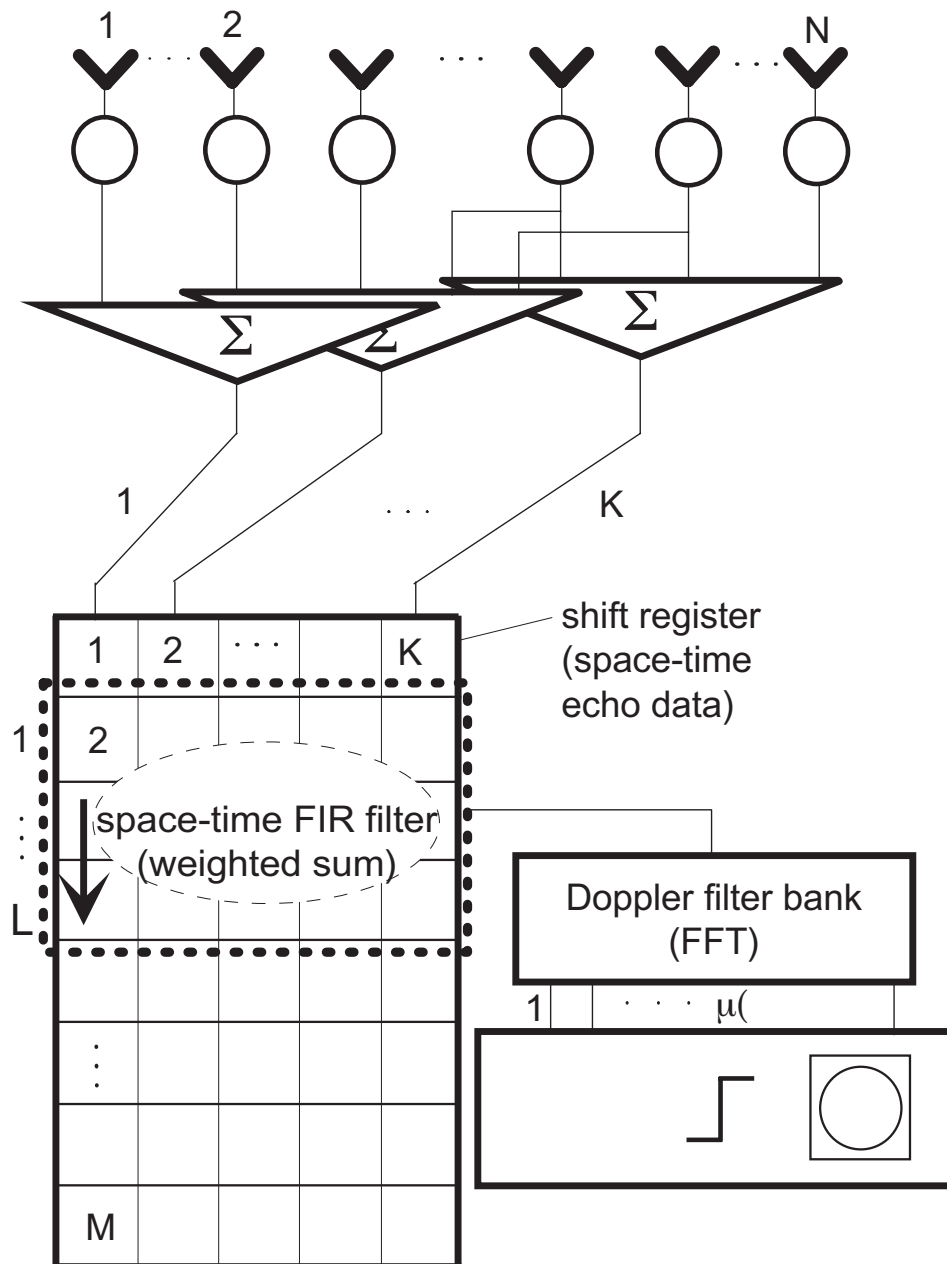
**Azimuth-Doppler Characteristics of a
STAP Filter for Sidelooking Array**

Space-time adaptive FIR filtering with staggered PRI

Subspace STAP techniques

- Space-time transforms (e.g. GSC concepts)
- Spatial transforms (reduction in the spatial dimension)
- **FIR filters** (reduction in the temporal dimension, => very efficient solution)
- Multi-stage filters
- Frequency dependent spatial processing (for large CPI only)
- Angle-Doppler subgroups (e.g. JDL-GLRT)
- others

Space-time adaptive FIR filtering with staggered PRI



Overlapping subarray processor with
space-time FIR filter

Space-time adaptive FIR filtering with staggered PRI

$$\mathbf{Q} = \begin{pmatrix} \mathbf{Q}_{11} & \mathbf{Q}_{12} & \cdots & \mathbf{Q}_{1M} \\ \mathbf{Q}_{21} & \mathbf{Q}_{22} & \cdots & \mathbf{Q}_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{Q}_{M1} & \mathbf{Q}_{M2} & \cdots & \mathbf{Q}_{MM} \end{pmatrix}$$

The space-time clutter+noise covariance matrix

$$\mathbf{K} = \mathbf{Q}^{-1} = \begin{pmatrix} \mathbf{K}_{11} & \mathbf{K}_{12} & \cdots & \mathbf{K}_{1M} \\ \mathbf{K}_{21} & \mathbf{K}_{22} & \cdots & \mathbf{K}_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{K}_{M1} & \mathbf{K}_{M2} & \cdots & \mathbf{K}_{MM} \end{pmatrix}$$

and its inverse

Space-time adaptive FIR filtering with staggered PRI

$$\mathbf{K} = \mathbf{Q}^{-1} = \begin{pmatrix} \mathbf{K}_{11} & \mathbf{K}_{12} & \cdots & \mathbf{K}_{1L} \\ \mathbf{K}_{21} & \mathbf{K}_{22} & \cdots & \mathbf{K}_{2L} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{K}_{L1} & \mathbf{K}_{L2} & \cdots & \mathbf{K}_{LL} \end{pmatrix}$$

The north-west $NL \times NL$ submatrix

(N number of antenna elements, L temporal filter length)

$$\tilde{\mathbf{K}} = \begin{pmatrix} \mathbf{K}_{11} \\ \mathbf{K}_{21} \\ \vdots \\ \mathbf{K}_{L1} \end{pmatrix}$$

The LS FIR filter matrix (1. Block column of inverse)

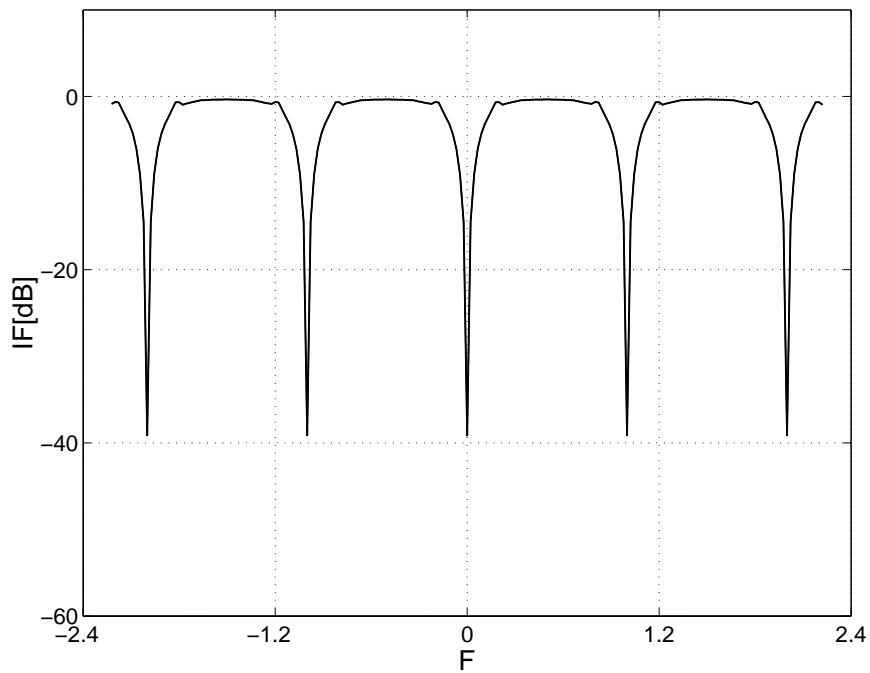
$$\mathbf{h} = \tilde{\mathbf{K}}\mathbf{b}$$

Further reduction: beamforming

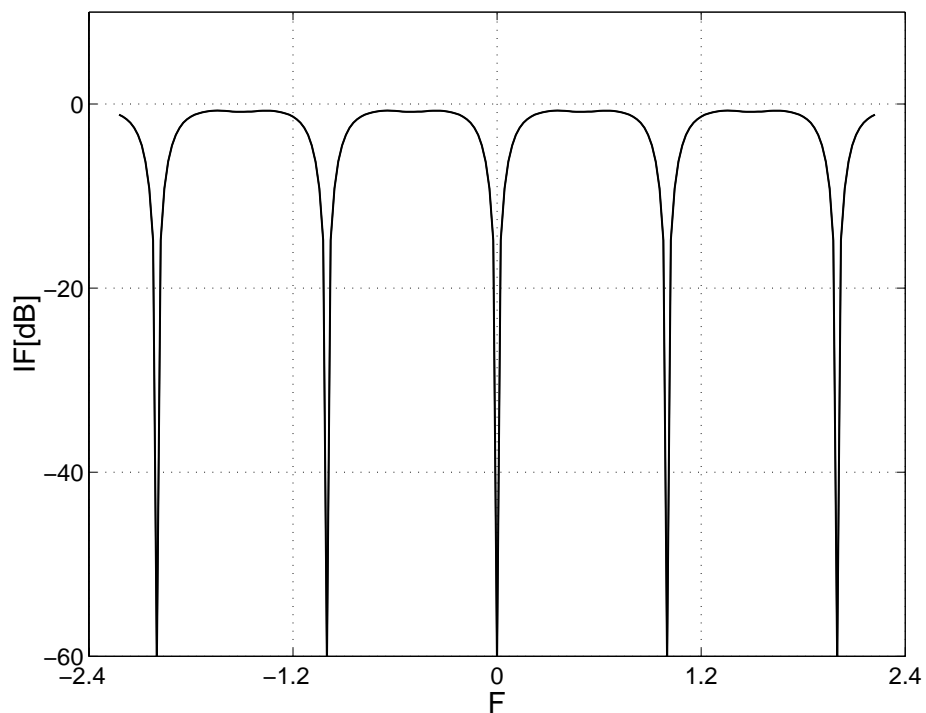
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Fully adaptive processing, constant PRI



FIR filter, 5 taps, constant PRI

Space-time adaptive FIR filtering with staggered PRI

a. $\epsilon=0$



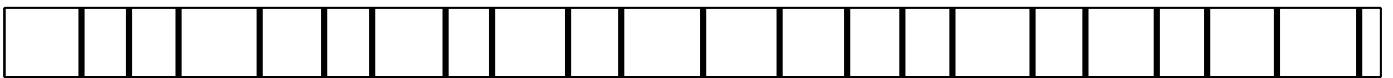
b. $\epsilon=0.03$



c. $\epsilon=0.1$



d. $\epsilon=0.3$

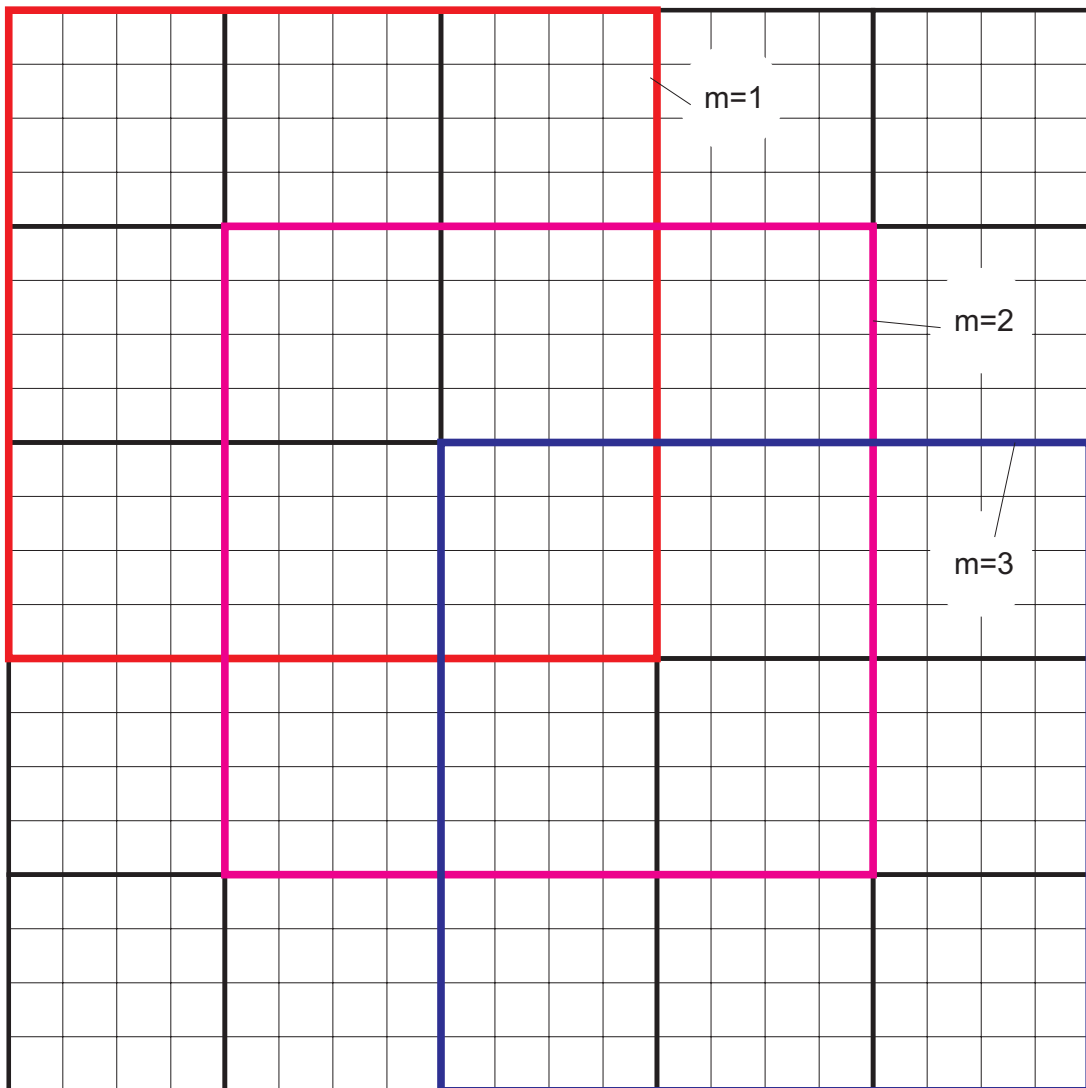


Pseudorandom PRI staggering

Properties of staggered PRI

- Avoidance of multiple clutter notches (blind velocities)
- Unambiguous target Doppler estimates
- Resistance against spot jammers
- However: no FFT for Doppler filter bank

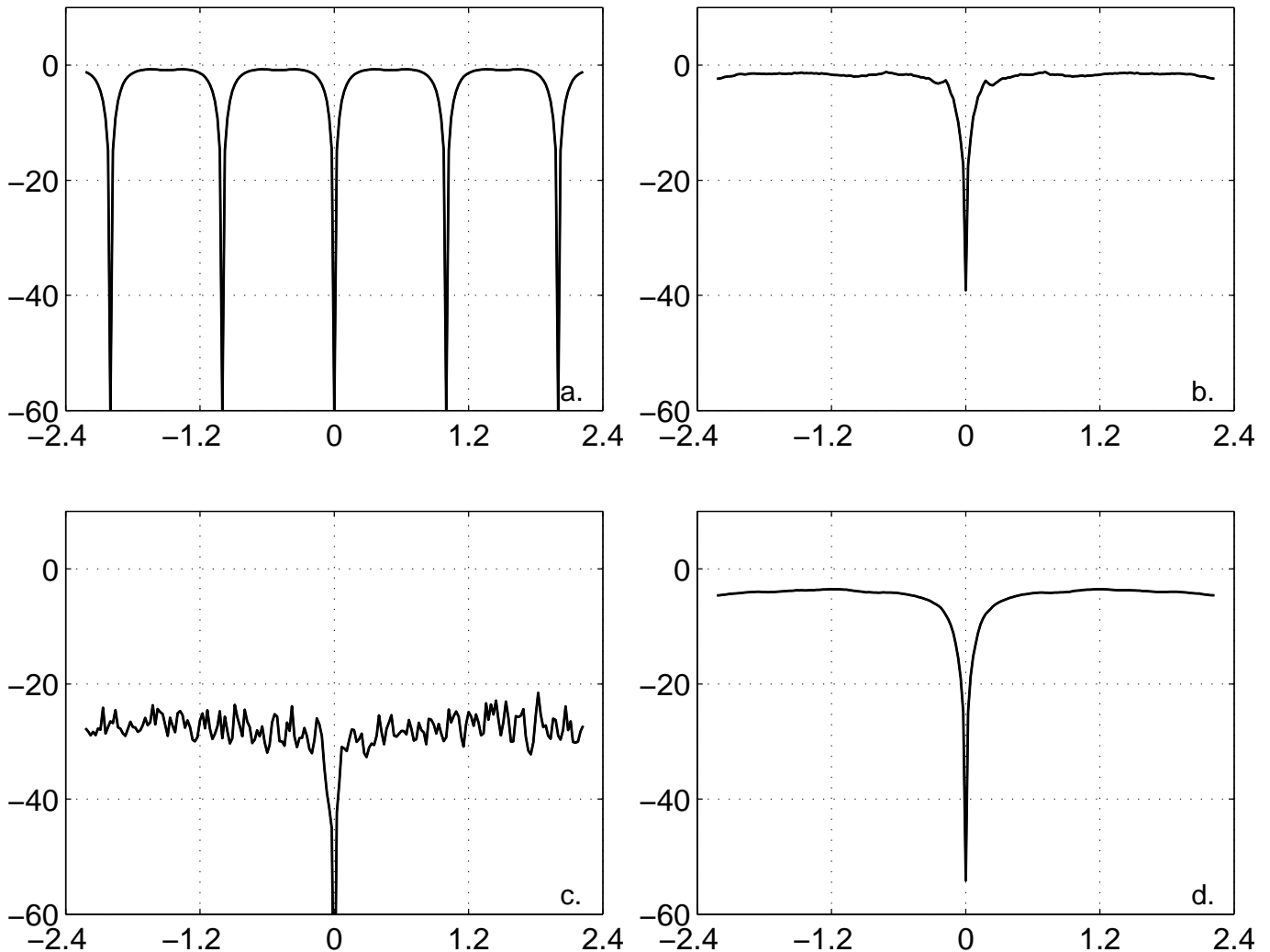
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- elements of spatial submatrices
- $K \times K$ spatial submatrices
- shifted diagonal space-time submatrices ($K=4$, $L=3$)

Matrix scheme for space-time FIR filtering
($K=4$, $M=5$, $L=3$)

Space-time adaptive FIR filtering with staggered PRI



Space-time FIR filter with staggered PRI

- a. optimum processing, **no staggering**, Nyquist sampling in space & time
- b. optimum processor, **staggered** PRI
- c. **fixed** ST FIR filter, **staggered** PRI
- d. **STAP FIR filter** with **variable** coefficients

Space-time adaptive FIR filtering with staggered PRI

Summary

- **Staggered PRI:** avoiding blind velocities (ambiguous) clutter notches, unambiguous estimation of target Doppler, resistance against spot jammers
- The **optimum (LR) STAP processor** can cope with staggered PRI
- The STAP **FIR filter** is a most efficient tool for real-time clutter rejection
- **FIR** filters with **constant coefficients** are mismatched to staggered echo sequences
- FIR filters with **varying coefficients** (readaption at every PRI)
- **Loss** compared with constant FIR filter and constant PRI: a few dB